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The Ecological and Economic Effects of Acid Rain

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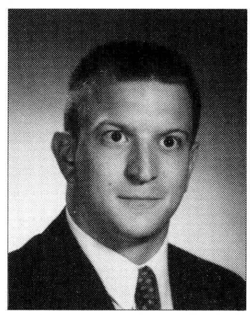

Introduction

The effects of acid rain on the environment are local as well as global, with both immediate and long range implications. An understanding of the acid rain phenomenon is critical to finding the proper solution. The catch phrase, "acid rain," has evolved to include all precipitation which has pH levels below that which would occur naturally and which are thus abnormally acidic. Precipitation itself is slightly acidic due to natural emissions from volcanic activity and nitrogen-producing bacteria. Once these emissions are introduced to the atmosphere, they become dissolved in suspended moisture. The mildly acidic solution that results is the cause of the normal weathering and erosion that recycles elements and is beneficial to the ecosystem overall.

The global concern lies with the various man-made emissions that have increased the acidity of the precipitation. Acid precipitation is responsible for the destruction of many natural ecosystems and man-made materials. Some of the damage is irreversible. It is now recognized that acid precipitation is threatening the existence of plant and animal life, and that appropriate action must be taken in order to control it.

The cause of acid precipitation is simply the emission of pollutants into the air, and the obvious solution would be to reduce the quantity of these pollutants. However, this is easier said than done. Government and industry are working on a balance between maintaining the environment and operating within practical economic constraints. The ultimate goal is the reduction of acid precipitation's effects at a cost which is justifiable in terms of the benefits received.

The resulting efforts of government regulators has evolved into the Title V provision of the amended Clean Air Act. This provision was tailored in order to mitigate the negative impacts on our economy. The cost of compliance will be born by consumers and industry in the form of increased fuel and utility costs, large scale capital expenditures, and unemployment.

The Causes and Sources of Acid Precipitation

Nature has functioned for centuries as a filter for its own emissions. This process, in which the gaseous elements return to the earth after dissolving in moisture that is suspended in the atmosphere, contributes to the overall life cycle. Recently, however, man has strained nature's ability to continue with this purifying process.

Sulfur oxides (SOx) and nitrogen oxides (NOx), which have been recognized as the major man-made pollutants, are the result of the combustion of fossil fuels. These pollutants are emitted in a gaseous form which, upon introduction to water vapor in the atmosphere, causes a chemical conversion process. By the mixing of gas and water vapor, new substances are created with lower than normal pH levels. Either the suspended acidic vapor or the gas molecules themselves can drift thousands of miles through the atmosphere. At any given time or place, nature will initiate a process that allows the vapors to return to earth as precipitation containing sulfuric and nitric acids.

The continued combustion of fossil fuels has emitted large volumes of pollutants leading to a decline in the quality of the air we breathe, otherwise known as ambient air. Blame for the acid precipitation problem lies with the use of fossil fuels to satisfy the nation's need for energy.The sulfur and nitrogen oxides in question are emitted from both mobile sources, such as motor vehicles, and in greater concentrations from stationary sources, such as utility plants.

Large industrial utility plants consume vast amounts of coal, which are laden with sulfur, to fire their furnaces. The process which generates electricity also creates by-products that all too often go up in smoke. Coal burning plants and other sources emit an annual national average of about 44 million tons of sulfur and nitrogen oxides. (Wright, p. 2) Locally, the problem is relatively minor. Effects of the emissions can be in the form of decreased visibility, such as a hazy cloud, or a noxious odor. However, the broader concern lies with the far-reaching effects that the emissions have, once introduced into the atmosphere.

Although utilities contribute greatly to the problem, it must be realized that they are not the only sources. Virtually any source which burns fossil fuels, such as the blast furnaces of steel plants, can have sulfur and nitrogen oxides traced backed to their emissions, and can therefore be considered large-scale contributors to the acid precipitation problem.

The Effects of Acid Precipitation on the Environment

The impact of acid precipitation can include disastrous effects on human health, water sources, vegetation, aquatic life, and man-made structures. There may even be other consequences of acid precipitation which are equally as destructive that are not yet known.

The most well known effect of acid precipitation is the acidification of lakes and streams. Rain, snow, sleet, and hail fall to the earth's surface, eventually working their way into either the ground water or lakes and streams. In earlier years, nature was able to buffer the naturally acidic precipitation, effectively neutralizing and eliminating any problem. The acidity levels of precipitation which now falls into remote areas, however, are so overpowering that nature's system of neutralization no longer works.

The effects of acid precipitation on water quality have been disastrous for aquatic life. Through direct deposit, runoff, or ground water flow, the acidic water makes its way into water bodies in which the pH levels are reduced to such an extent that aquatic life cycles are disrupted. The effects can take the form of disruptions of the reproductive cycle, malformations of aquatic creatures, as well as outright death. The effects can also work their way up the food chain from the smallest bacteria, and can thus have significant repercussions on more advanced forms of life.

Forest decline is another well-documented result of acid precipitation. Foliage is damaged by direct contact with precipitation and through root absorption. Trees become deformed and even the death of whole forests occurs in the affected areas.

Agriculture can also be harmed by acid precipitation's effects on soil. There was a time when the natural acidic properties of rain water were necessary to dissolve minerals in the soil for later plant absorption. Now, however, the unnaturally high acidic levels of precipitation have dissolved greater quantities of minerals, thus destroying soil quality. While alkaline levels in soils can be adjusted and hybridization can develop new stains of plants capable of surviving, the long term consequences have not yet been fully determined.

Damage to rock formations is still another one of the obvious effects of acid precipitation. Although the weathering of rock formations is part of the natural process of replacing minerals, once again nature is overburdened The presence of acid precipitation has accelerated the weathering process of rock formations beyond natural levels.

Perhaps the most visible consequence of acid precipitation is the damaging effects it has upon on marble statues and tombstones. Features and writing are no longer distinguishable on some of the affected structures due to the corrosive effects of the precipitation. Tombstones, for example, are crumbling and their markings are becoming illegible. The aging process of structures such as concrete bridges in industrialized areas has been accelerated and is creating a safety hazard and financial burden for municipalities. Moreover, the finishes on buildings and other man-made objects such as automobiles are frequently encountering rains with pH levels as acidic as lemon juice or vinegar, which results in the premature aging of their finishes or exterior.

Human health can be affected in many ways as well. Extremely large levels of metals can be released by acid precipitation and become dissolved in solution. If ingested, this can lead to toxic heavy metal poisoning directly, or it may be passed on through the food chain. Acid-contaminated water, when coming in contact with household plumbing, can dissolve lead-based solder and contaminate drinking water, thus posing a direct threat to human health. The consumption of aluminum, for example, has been linked to Alzheimer's disease. (Luoma, p. 18) Another form of acid precipitation, known as dry deposition, is an acidic substance in a dry solid shape which when inhaled can cause respiratory complications. Asthmatic conditions especially could be worsened due to dry deposition exposure. The extent of the dry deposition problem is still somewhat uncertain due to the difficulties of conducting the precise monitoring of this phenomenon. (Luoma, p. 16)

Solutions to the Acid Precipitation Problem

Although the most obvious solution, the banning of fossil fuels, is not a viable alternative at this time, conservation may be. By reducing the use of current energy sources, the levels of acid precipitation reactants discharged will decrease as well.

There are many other proposed solutions that can be implemented to solve the acid precipitation problem. Reduction of the emissions which are at the source of acid precipitation can be achieved by the use of alternative energy sources. And if alternative sources are not sufficient, remedies can be found in all phases of the combustion process which generates the energy from the fuel used. A solution commonly used in the past was to build smokestacks higher to eliminate the local problem of the noxious odors and ashes. However, while higher smokestacks solved the local problem, a more far-reaching global problem was created.

Substitution of alternative sources in place of fossil fuels is one of the newer methods of reducing the acid precipitation problem. Alternative sources of power such as nuclear, hydro, or solar could provide clean energy that would not produce the by-products that endanger the environment. However, the use of alternative sources can have possibly even more harmful effects on the environment, such as the disposal of hazardous waste.

One innovative method of emission reduction at the pre-combustion stage is the desulfurization or denitrification of fuels or emitted gases. The switch to fuels that are naturally low in sulfur content, such as low sulfur coal, would greatly reduce the problem at the source. This method would require switching from coal suppliers in Northern Appalachia and the Midwest, where coal is high in sulfur, to sources such as Central Appalachia and the West, where the sulfur content of coals is much lower.

Another method for reducing sulfur oxide emissions at the pre-combustion stage is by removing the sulfur content of the fuel before it is burned. Methods of desulfurization include coal cleaning, coal gasification, and the removal of the sulfur content from liquid fuels.

Sulfur content can also be reduced during the combustion stage of the production cycle. A process known as atmospheric fluidized-bed combustion removes the sulfur content of the emission. This process entails mixing fine coal particles and limestone with a turbulent blast of air. The mixing of coal and air allows for combustion at a lower and more even temperature, which reduces the formation of sulfur oxides.

Another combustion-stage method of emission reduction involves pressurized fluidized-bed combustion. The sulfur content of the emissions is removed in this method by the buffering nature of limestone. The process captures the sulfur emissions under compressed air. By utilizing pressurized fluidized-bed combustion, plant efficiency can also be increased.

The gasification/combined-cycle process is yet another emission reduction technology that is implemented during the combustion stage. Here steam and air react together with coal to produce a gas consisting of hydrogen and carbon monoxide. This gas can be burned, and the waste steam of the process can also be utilized to turn a turbine. Levels of sulfur and nitrogen oxide emissions are significantly reduced using this method.

Nitrous oxide contributions to the acid precipitation problem can also be reduced during the post-combustion process. Stationary source reduction of nitrous oxides is primarily accomplished by lowering the combustion temperature, because at lower temperatures there will be fewer emissions. A negative side effect of this process is that a portion of the fuel is not utilized because of the low temperature. Nitrous oxide production can also be traced to mobile emission sources (e.g., automobiles). Similarly, mobile source reductions of nitrous oxide emissions can be lessened by reducing engine operating temperatures of motor vehicles.

Emissions can also be reduced during the final stage of the combustion process (post-combustion). During post-combustion desulfurization occurs as the gas is traveling through the exhaust stack. "Scrubbers," or gas desulfurization systems, as part of the stack design can greatly reduce the amount of sulfur oxides released into the atmosphere. (EPA, p. 28) For mobile sources, one common approach to the removal of both nitrous oxides and other harmful gasses is through the installation of catalytic converter systems. (EPA, p. 29)

Implementing the Proposed Technology – Retrofitting and Repowering

The control of acid precipitation at its source has become a project of unforeseen magnitude. There are many large industrial plants operating throughout the United States, Canada, and the rest of the world that were built before the control of emissions was contemplated.

The need has thus arisen for modifications to existing plant designs. The least costly process is to retrofit emission reducing technology. Retrofit technologies are designed to be installed on existing capital equipment without necessitating any major changes. The installation of an emission cleaning device on an already existing plant, such as a flue gas desulfurer(scrubber), is one such example of retrofit technology. The base capital cost of retrofit technology may exceed 133 dollars per kilowatt of plant capacity. However, retrofit technology can reduce regulatory compliance costs significantly, and may have further impacts on the overall cost of compliance. (ICF, p. C-3)

An alternative method of implementing pollution control technology in existing plants is by repowering. Repowering consists of a major modification to existing equipment and is in fact a substitute for the construction of a new plant.When a plant undergoes repowering, it usually not only reduces emissions but also decreases costs through greater capacity and increased efficiencies. The costs associated with repowering are extremely high, however, with the capital cost of compliance using repowering technology sometimes exceeding

$765/kw. (ICF, p. C-5) Other considerations regarding the repowering alternative include capacity needs, fuel requirements, and government regulations. (Parker, p. CRS5)

Thus far the discussion has been limited to the control of existing sources of emission contributors. The absence of strict federal legislative regulations in the past has delayed the development and availability of technology that is capable of controlling the source pollutants. (Parker, p. CRS13)

Controlling Acid Precipitation through the Market Mechanism

In addition to solely technological means, another method of controlling the acid precipitation problem would be to develop a market system that would allocate emission rights. Emission rights would be traded on an open market much like any other resource by the creation of permits. The limited number of emission-right permits would promote economic efficiency, thus causing the reduction of emissions through market forces. Such a proposal would reward the efficiently run operations with large-scale pollution reductions by allowing them to receive credit for the amount that they "under-emitted." Credits not used, or emissions that fall under government standards, can then either be saved for future use or traded on the market to other firms that are not running as efficiently. This would lead to an incentive for more efficient operations and thus to reduced emissions. (Shabecoff, p. A18)

There are two proposed methods for the implementation of a system of marketable permits. The first, flexible implementation, would allow the trading of emission rights to include interstate trading. With a flexible system, credits could be traded on a national level and a larger market would result, with firms receiving a more equitable market value for the emission credits. The other proposal, termed constrained implementation, would restrict the trading of emission allowances to the intra-company level, or only among sources that a company has control over. This would restrict the market exposure of the credits but would still allow for gradual improvement in emission levels. Through either method of implementation, it would eventually become economically efficient for polluting companies to emit below their allowances. (ICF, p. 25)

Also included in emission trading proposals is the exchange of nitrous oxide reductions for the required sulfur oxide reductions. Some companies may have the ability to make further reductions in their emissions of nitrous oxides as compared to their production of sulfur oxides. By adding the flexibility to allow for such an option, emitting sources can find it worthwhile to engage in such trades while simultaneously meeting the overall goal of environmental responsibility. (ICF, p. 27)

A concept similar to emission trading is that of emission banking. With emission banking a company may exchange credit received from currently emitting below required levels in exchange for lower reduction requirements in the future. This can be especially useful for a company which chooses to increase emission reductions and costs at an early stage when the marginal costs are low, and decrease later reductions and costs at some time in the future. (ICF, p. 25)

The Economic Impact of Acid Precipitation Compliance

The effects of acid precipitation extend well beyond the environment. In fact, the economic consequences of acid precipitation affect nearly everyone. When a regulatory response such as the Clean Air Act involves a common property resource, such as air, markets may fail due to the presence of an externality. An externality occurs when the actions of a producer or consumer impose costs or benefits on another. The party distributing the costs or benefits must transmit them through a mechanism other than through market prices. The acid precipitation issue is a classic example of an externality. The costs associated with acid precipitation have been imposed on people who are removed from those receiving the benefits created through the emission process. The costs of meeting the regulatory response to control the acid precipitation abuse have been estimated to be in the billions of dollars. And the bulk of these costs will not be borne by the polluting industries, but will be passed on to the end user.

In the course of the evaluation of the economic impact of acid rain and its control, there are many areas of concern. However, it is first necessary to consider the Clean Air Act and focus on its proposed emission reductions before an analysis can begin. The Act is designed to solve the acid rain problem in two phases. The first phase, to be accomplished by 1995, has a reduction goal of approximately five million tons of sulfur oxide below the current annual emissions rates of 44 million tons of both sulfur and nitrogen oxides. The second phase mandates annual reductions of 10 million tons of sulfur oxides by the year 2000, at which time a nationwide cap on sulfur oxides would be in place. During the second phase an additional goal has been established. Utilities will eventually be required to cut nitrous oxide emissions by 25 per cent beginning in 1995 with an annual reduction of two million tons. There are many additional detailed provisions contained in Title V of the Clean Air Act. However, the fundamental reduction requirements mentioned above serve as the basis for the rectification of the damage. (Gutfeld, p. A7)

The Effects on National Utility Costs

The costs to be borne by utilities through the year 2000 have been estimated to be roughly \$13 to \$18 billion on a present value basis. Phase one annual costs are estimated to be about \$1/2 billion dollars per year, while the second phase costs may exceed \$3.3 billion per year. To put these numbers into perspective, the total annual costs of compliance for Title V will be \$4.1 billion per year — all of this in addition to the \$33 billion per year that is already spent on pollution control. (Rosewicz, p. A1)

There will also be significant effects of the Clean Air Act on the rates charged to the end-user. Nationally, electricity rates can be expected to rise 1-2 percent if flexible implementation of emission trading rights is enacted, while rates will rise about 2 percent with the constrained implementation of trading rights.

Estimates of the long term cost of compliance project electrical rate increases to be below five percent by the time operations are in full compliance. Resident-rate payers in some states will have to absorb a larger share of the burden, because the electric utility plants that require greater capital expenditures in order to comply are located within those states. Although the average rate impact within some states will be low, some areas in these states may be harder hit if there are stringent limitations on emission trading. In fact the proposed constrained implementation plan may limit the trading of emission rights to such an extent that it may not have any effect on small plant operations. (ICF, p. 17)

The Impact on Coal Markets and Mining Employment

The necessity to switch from the high-sulfur coals of Northern Appalachia and the Midwest to the low-sulfur coals of Central Appalachia and the West will also have a tremendous impact on coal usage. Phase one reduction requirements will be partially met with the switch from high- to low-sulfur fuel. During this phase there would be a reduction of from 50 to 55 million tons of high sulfur coal used, depending upon whether constrained or flexible implementation of trading rights is put into place.

Phase two will see further reductions in the use of high sulfur coal, ranging from 109 to 119 million tons per year under constrained implementation, and slightly lower tonnage levels under flexible implementation. However, forecasters predict a revival of the high sulfur coal market once new clean coal technologies are in place and more efficient scrubbers are retrofitted. (ICF, p. 19)

Overall coal production is not expected to be affected, due to the fact that losses in one market will be offset by gains in the other. However, there will be shifts in employment from regions of high-sulfur coal to those with more environmentally sound low-sulfur coals. The Midwest and Northern Appalachia can expect to see a loss of about 17,000 coal mining jobs to regions producing low-sulfur coal when Title V's requirements are fully met. Pennsylvania is expected to be hit the hardest as a result of the Title V provision. When taking these facts into consideration, one must also realize that the movement of jobs from one area to another can have a drastic impact on local economies generally, as well as on the unemployed mining population. Nationwide there will be a net loss of approximately 7,000 jobs because the heavily demanded low sulfur coal tends to be strip mined. (Kennedy, p. 86) The Clear Air Act's final version includes a provision which will allow the unemployed miners to qualify for extra weeks of unemployment pay under a $250 million job assistance package. (Gutfeld, October 1990 p. A7)

Corporate Financial Considerations

Title V is expected to cost Americans over 4 billion dollars per year beyond what they already pay for pollution control. The immediate effect of this will be major financial restructuring for corporations prior to the passing of the expense to the end user. The various technologies that will be required to comply with the EPA's regulations will translate into tremendous capital expenditures.

David M. Anderson, general manager of environmental affairs at Bethlehem Steel Corporation, indicated his concern in this regard by saying that the expected environmental outlay alone could entirely wipe out the steel industry's capital budget, which is currently around two billion dollars per year. (Ansberry, p. A71) The acid precipitation legislation will have even greater financial effects on larger polluters, such as the utilities. Necessary capital expenditures for compliance will also cause a rise in activity in the debt and equity market segments of the affected industries. The rise in capital expenditures may also cannibalize other spending within the affected industries and result in decreased research and development, which could in turn affect future profitability and growth.

Other Impacted Areas of the Economy

Acid precipitation imposes other costs on the economy in addition to those previously mentioned. Forestry, man-made materials, agriculture, and the recreational activities of fishing and sightseeing have all been financially damaged due to acid precipitation's effects.

It is difficult to quantify precisely the cost of acid precipitation on forests, for there are many variables to consider. In addition to exposure to abnormally low pH level rainfall, such factors as forest management, rainfall quantity, and disease can also alter forest growth patterns. It is by measuring growth that profitability is determined in the forest industry. Consequently, reduced growth rates translate into losses for the forest industry, and reductions of from 10 to 40 percent caused by acid precipitation have occurred in various regions. The annual cost of this reduced growth to the forest industry has been estimated at $342 million for a 10 percent reduction in forest growth to $510 million for a 20 percent reduction.

Determining the cost of acid precipitation's damage to man-made materials and structures again faces the problem of controlling for the effects of other variables. A recent report of the Army Corps of Engineers placed an annual cost of $5 billion on damage caused to man-made materials and structures in a 17 state area alone. (Kennedy, p. 93) However, the National Acid Precipitation Assessment Program (NAPAP) severely criticized this figure while coming up with its own estimate of $107 million a year. This example of widely differing damage estimates, each presented by highly respected sources, further illustrates the difficulties involved in determining precisely the costs of acid precipitation.

NAPAP also reported varying estimates on the cost of acid precipitation to the agricultural sector. NAPAP studies reveal that while some crops are affected by acid rain, others are not; indeed some plants actually thrive on the nitrogen-enriched water from the dissolved gas in the atmosphere, with a resulting savings in fertilizer expenditures. NAPAP's estimate of damages caused by acid precipitation in this sector were estimated to be $150 million while savings were estimated to be $161 million. However, these estimates may not take into full account the damage done to the original soil properties and chemistry that were in balance before being exposed to higher concentrations of acid precipitation.

The available estimates of the cost of acid precipitation on recreational fishing and scenic vistas are even more uncertain. Here, too, many additional factors come into play, such as travel times and individual preferences. However, what many would argue is that nature, like life itself, is priceless, and that the damages that have occurred so far are enormous. (Kennedy p. 82)

Conclusion

It is still too difficult to quantify precisely the full extent of the costs associated with acid rain. Nevertheless, we still must consider whether the enormous expenditures that are to be made on its control will be worth the strain on the economy in the long run. The annual projected expenditures of $4 billion is higher than anyone originally anticipated, with the expected costs of abiding by the Title V provision of the Clean Air Act to be even greater. In any case, with the recognition of the damage that has already occurred, a major step has been taken. However, the laborious task of finding and implementing the most appropriate solution still challenges all involved.

REFERENCES

Ansberry, Clare. "Steelmakers See Clean Air Bill Costing Them $5 Billion Over the Next Five Years." *The Wall Street Journal*, May 25, 1990, p. A7.

Blodgett, John and Mira Courpas. "Air Quality Legislation." CRS Issue Brief, April 1990.

Backiel, Adela. "Acid Rain, Air Pollution, and Forest Decline." CRS Issue Brief, May 1990.

Corbett, Edward S; Jeffery W. Grimm; and James A. Lynch. "Atmospheric Deposition: Spatial and Temporal Variations in Pennsylvania—1988." Penn State Environmental Resources Institute, December 1989.

Courpas, Mira and Larry Parker. "Acid Rain Legislation in the 101st Congress." CRS Issue Brief, April 1990.

Environmental Protection Agency. "Acid Rain." Office of Research and Development, July 1980.

Frey, Bob; Wick Havens; and John Slade. "Pennsylvania Perspective on Acid Rain." Commonwealth of Pennsylvania, Department of Environmental Resources, February 1990.

ICF Resources Incorporated. Economic Analysis of Title V of the Administration's Proposed Clean Air Act Amendments (H.R.3030/S.1490). US Environmental Protection Agency, September 1989.

Luoama, Jon R. "The Human Cost of Acid Rain." *Audubon*, July 1988, pp. 16-29.

Gutfeld, Rose. "Senate Rejects 50-49 Byrd Amendment To Clean Air Bill on Aid to Coal Minors." *The Wall Street Journal*, March 30, 1990, p. C13.

Gutfeld, Rose. "For Each Dollar Spent on Clean Air Someone Stands to Make a Buck." *The Wall Street Journal*, October 29, 1990, pp. A1 and A7.

Kennedy, David M. "Controlling Acid Rain." John F. Kennedy School of Government, Harvard University, 1986.

Manson, Alex N. "Acid Rain: The Canadian Perspective." *State Government News*, September 1988, pp. 16-17.

"Acid Rain: States Resolve Conflict." *State Government News*, September 1988, pp. 18-19.

Mohned, Volker A. "The Challenge of Acid Rain." *Scientific American*, August 1988, pp. 30-38.

Parker, Larry. "DOE's Clean Coal Technology Program: Goals and Funding." *CRS Issue Brief*, May 1990.

Rosewicz, Barbara. "Clean Air Legislation Will Cost Americans $21.5 Billion a Year." *The Wall Street Journal*, March 28, 1990, pp. A1 and A16.

Shabecoff, Phillip. "Environmental Bill Sent to White House." *The New York Times*, April 6, 1990, p. A18.

Stevens, William K. "Worst Fears on Acid Rain Unrealized." *The New York Times*, February 20, 1990, p. C11.

Wright, John. "Acid Rain." Pennsylvania Department of Environmental Resources, News release, September 1988.